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Original Research Article

Climatic Variables on the Prediction of Raffia Palm Wine Yield in Ikot Ekpene Local Government Area of Akwa Ibom State, Nigeria

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Abstract: This research was aimed to examine Raffia palm wine prediction based on climatic data in Ikot Ekpene Local Government Area of Akwa Ibom State, Nigeria. The secondary sources of data include meteorological records obtained from the Nigerian Meteorological Station, and raffia palm wine yield obtained from the Ministry of Agriculture, Uyo. The autoregressive integrated moving average (ARIMA) model was used to analyze climate variables and raffia palm wine yield. The result shows that the best ARIMA model for rainfall for Ikot Ekpene was (0, 1, 4) and (1, 1, 1) with AICC values of 9.912292 and 10.02025 and SC values of 10.00659 and 10.16652. The minimum temperatures for Ikot Ekpene were (1,1,1); (1,1,0) and (0,1,1), and the corresponding AICC values of 1.255038, 1.213633 and 1.271621, SC values of 1.397774, 1.308790 and 1.365917. The ARIMA model for raffia palm wine for Ikot Ekpene were (0, 1, 1) and (1, 1, 1) with AICC values of 12.48799 and 12.34525 and SC values of 13.07993 and 12.48799. The model efficiency was checked using the sum of square error (SSE), mean square error (MSE), Mean absolute per cent error (MAPE) and root mean square error (RMSE), respectively. The results of the various analyses indicated that the models were adequate and can aid future climatic and raffia palm wine projections. The researchers recommended that appropriate climate forecasting and early warning systems should be made part and parcel of planning and development to increase the yield of raffia palm wine, to improve the local dry gin industry.

Keywords: Arima, Forecasting, Rainfall Model, Temperature, Raffia Palm Wine Yield.

1. INTRODUCTION

Crop production is a complex phenomenon that is influenced by agro-climatic input parameters. Agriculture input parameters vary from field to field and farmer to farmer. Collecting such information in a larger area is a daunting task. The huge amount of such data sets can be used for predicting their influence on major crops of that particular district or place. In the prediction of meteorological information, the investigation and analysis of precipitation is so essential (Radhakrishnan and Dinesh, 2006), and an accurate forecast of precipitation is crucial for improved management of water resources, particularly the arid environments (Feng *et al.,* 2015). The study by Somvanshi *et al.,* (2006) saw rainfall as a natural climatic occurrence and its prediction remains a difficult challenge as a result of climatic variability. The forecast of precipitation is particularly relevant to agriculture, the growth of plants and development, which profoundly contribute to the economy of Africa. The forecast of rainfall and temperature is a difficult task due to their variability in time and space and the inability to access all the parameters influencing the rainfall of a region or locality. Their forecast is of relevance to agriculture and watershed management, which significantly contribute to the economy. Rainfall prediction requires mathematical modelling and simulation because of its extremely irregular and complex nature. In the statement of the above authors, attempts have been made to predict the behavioural pattern of rainfall using the autoregressive integrated moving average (ARIMA) technique. ARIMA model is fundamentally a linear statistical technique for modelling time series and rainfall forecasting with ease to develop future predictions. Though rainfall estimation is an important component of water resources planning, its accurate assessment at locations where rainfall stations are scarce can be very difficult.

This estimates rainfall a valid concern using the right method. Thus, in the empirical hydro-meteorological modelling of time series data, the emphasis is on modelling and predicting the mean characteristic of the time series using the conventional methods of an autoregressive moving average (ARMA) technique propounded by Box *et al.*, (2015).

In agricultural planning, the understanding of rainfall variability and its prediction has great significance in agricultural management and helps in the decision-making process. Rainfall information is an important input in hydrological modelling, predicting extreme precipitation events such as droughts and floods, for planning and management of irrigation projects and agricultural production is very important (Nirmala 2015). The surface air temperature (SAT) represents an important element of a regional climate. Therefore, maximum and minimum values of SAT are usually used as input in various environmental applications, including agriculture, forestry, fisheries and ecological models to predict likely changes at field and landscape level attributes (Kumari *et al.*, 2012). During the twentieth century and currently, one of the topical issues discussed extensively among researchers and scientists in the field of climate change is changes in SAT. The likely impact of a rise in temperature on human beings, which is a global phenomenon, is being pondered over by a host of scientists. Kapoor (2013) reported that considering all the climatic variables, forecasting temperature variability is very essential for diverse applications. Applications of temperature prediction are for climate monitoring, drought detection, agriculture and production, planning in the energy industry and many others. In a related study by Kenitzer 2007), they argued that temperature forecasting is the most essential service delivered by the meteorologist to safeguard the life and property of dwellers in a locality and also to improve the efficiency of operations and to aid individuals in planning a wide range of activities daily.

In Ghana, several studies have been conducted in recent times to analyse and forecast rainfall and temperature change using the techniques of ARIMA modelling to assess the changes in rainfall and temperature regime both at the national, regional and watershed levels (Abdul-Aziz *et al.*, 2013; Asamoah-Boaheng, 2014). A search of the literature revealed the gap of no rainfall and temperature analysis and forecast using the ARIMA model exist in the Tordzie watershed. The Tordzie watershed is an important in the Volta region of Ghana. It has an enormous economic benefit for its catchment dwellers. The water from the watershed serves as a source of drinking water, washing, watering animals, irrigation, etc. The forecast model will be of tremendous assistance to the National Disaster Management Organisation (NADMO). Further analysis of the forecast rainfall and temperature will alert them to prepare for disasters like drought and flood. These hydro-meteorological disasters result in the loss of life and property and millions of dollars are spent in assisting the victims of such natural calamities. A shortcoming in the agencies responsible for disaster management in Ghana is the weak capacity to forecast this event ahead of time to inform the general populace to prepare or find a place of safety. Thus, this study is to aid and complement the effort of the decision-makers and those responsible for the safeguarding of life and property to plan for the future (Afrifa-Yamoah *et al.*, 2016). The result will further engender community resilience in terms of preparedness, mitigation and adaptation strategies. This study is novel research in Ikot Ekpene, in which the ARIMA model was used to predict the yield of raffia palm wine with the aid of climatic variables to know what will happen to the tree crop in the future. The overall objective of this study is to determine which ARIMA model is the best suited to predict the future rainfall and temperature in Ikot Ekpene Local Government Area.

2. METHODOLOGY

Historical rainfall and temperature data were collected from the Akwa Ibom State International Airport. The data continues. The present study was aimed at developing a website for finding out the influence of climatic parameters on crop production in Ikot Ekpene. The selection of this area has been made based on the area under that particular crop. The crops selected in the study are based on the predominant crops in the selected area. The selected crop is raffia palm wine. The yield of the crop was tabulated for 5 years by collecting the information from secondary sources. Similarly, for the corresponding years, climatic parameters such as Rainfall and Maximum temperature, were also collected from the secondary sources.

The annual data on raffia palm wine yield was obtained for the period 2018 – 2024. These data were used in predicting the future values of raffia palm wine yield based on climatic variables in Ikot Ekpene using a (4) linear time series model, also known as Auto-Regressive Integrated Moving Average (ARIMA), which is the most general class of models for forecasting a time series. Different series appearing in the forecasting equations are called the "Auto-Regressive" process. The appearance of lags of the forecast errors in the model is called the "moving average" process. The ARIMA model is denoted by ARIMA (p,d,q), where "p" stands for the order of the auto-regressive process, 'd is the order of the data stationarity and 'q' is the order of the moving average process.

The autocorrelation function (ACF) and partial autocorrelation function (PACF) were used to identify the models with the aid of visual inspection. Stationarity tests were conducted using the augmented Dickey–Fuller (ADF), Akaike Information criterion (AIC) and Schwarz Criterion (SC) tests, respectively. The chosen models were evaluated and validated using the Akaike information criterion corrected (AICC) and also Schwartz Bayesian criteria (SBC). The diagnostic analysis of the models comprised the independence, normality, homoscedasticity, *P–P* and *Q–Q* plots of the residuals, respectively.

3. RESULT AND DISCUSSIONS

3.1. Results

The predictions for values of climate variables derived from the trend models for annual rainfall, T_{min} and RPWY, respectively, are presented in Table 1. This prediction is also presented graphically in FIG.1 – 3. For the prediction of climate variables and RPWY, Autoregressive Integrated Moving Average (ARIMA) was used for this forecast. The forecasted values revealed that annual rainfall will increase from 2023 – 2030 to 421.6665mm – 477.8097mm with a difference of 56.1432mm. This implies that values of rainfall are projected to be increasing signifying that flood could be experienced in the area if the trend continues. The T_{min} will also increase to 24.66634ºC in 2030. The result for the prediction of RPWY in Ikot Ekpene shows that there will be a reduction from 2023 – 2030, which is 4629.782 litres – 4500. 837 litres with a difference of 128.945 litres. This prediction means that there will be 128.945 litres of raffia palm wine loss in the next eight (8) years due to the variation in climate. Conclusively, it means that there is a negative signal that there will be a decrease in RPWY in the future unless adaptive measures are taken to tackle the climate variability in Ikot Ekpene Local Government Area.

Table 1: Predicting climate variables and RPWY from 2023 – 2030

Year	Annual rainfall (mm)	T_{min} (ºC)	Raffia Palm Wine Yield (litre)
2018	381.5648	23.84239	4721.887
2019	389.5847	23.91105	4703.466
2020	397.6051	23.97972	4685.045
2021	405.6256	24.04838	4666.624
2022	413.6460	24.11704	4648.203
2023	421.6665	24.18570	4629.782
2024	429.6870	24.25436	4611.362
2025	437.7074	24.32303	4592.941
2026	445.7279	24.39169	4574.520
2027	453.7484	24.46035	4556.099
2028	461.7688	24.52901	4537.678
2029	469.7893	24.59768	4519.257
2030	477.8097	24.66634	4500.837

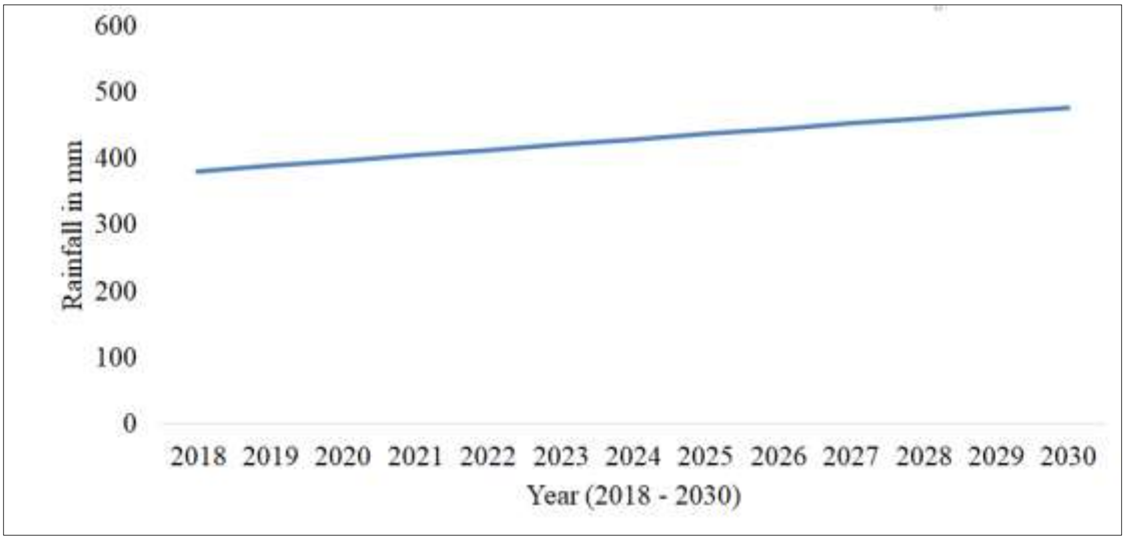

Figure 1: Chart showing the forecast values of Rainfall in Ikot Ekpene from 2018-2030

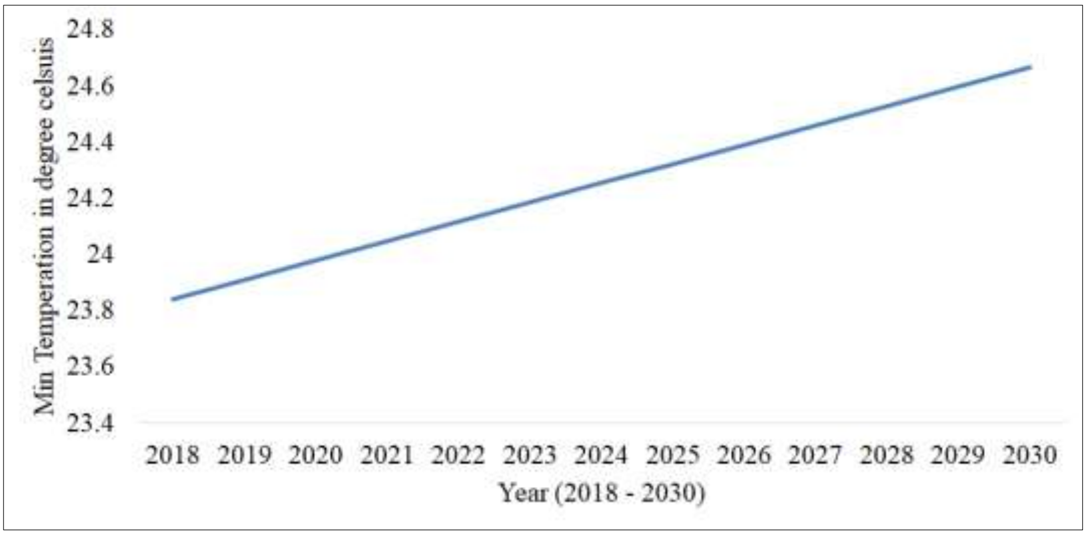

Figure 2: Chart showing the forecast values of Minimum Temperature in Ikot Ekpene from 2018-2030

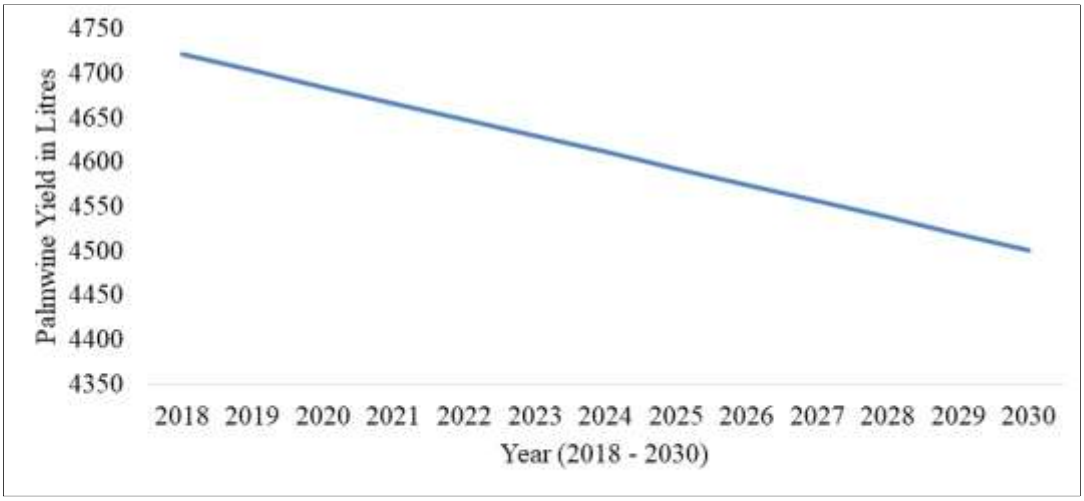

Figure 3: Chart showing the forecast values of RPWY in Ikot Ekpene from 2018 – 2030

Two tentative ARIMA models were tested and the model that had low Akaike Information Criterion (AIC) and Schwarz Criterion (SC) were selected for climate variables and raffia palm wine yield. Therefore, the most suitable model was ARIMA (1,1,1) for RPWY. For annual rainfall two ARIMA models were used while in T_{min} three ARIMA models were considered respectively. ARIMA (0,1,4) for annual rainfall and ARIMA (1,1,0) for T_{min} had the minimum values. The models and corresponding AIC and SC values are shown in Table 2–4.

Table 2: ARIMA modification for annual rainfall

ARIMA	Akaike Information criterion	Schwarz Criterion
0,1,4	9.912292	10.00659
1,1,1	10.02025	10.16652

Table 3: ARIMA modification for T_{min}

ARIMA	Akaike Information criterion	Schwarz Criterion
1,1,1	1.255038	1.397774
1,1,0	1.213633	1.308790
0,1,1	1.271621	1.365917

Table 4: ARIMA modification for RPWY

ARIMA	Akaike Information criterion	Schwarz Criterion
0,1,1	12.48799	13.07993
1,1,1	12.34525	12.48799

3.2. Discussion

In this study, the forecasted values for annual rainfall from 2023 - 2030 were tested using ARIMA models. These values were then compared to the true value obtained from 2018 – 2022 in Ikot Ekpene to evaluate the forecasting performance. The best model used to forecast RPWY in Ikot Ekpene was chosen based on its forecasting performance. Forecasting results were indications for the extent of the contribution of the Ikot Ekpene tappers to the overall RPWY in the area. This study only considers the time series data of annual rainfall, T_{min} and RPWY for forecasting purposes and excludes T_{max} because it was insignificant, however, there could be other factors that might affect RPWY, such as soil characteristics, ecological factors, variety of raffia palm, pests and diseases. Further studies will be conducted to include these yield parameters in multivariate models thus providing a more accurate prediction of raffia palm wine. As a result, the future study of this research is to apply other available model to forecast RPWY that incorporates more agriculture parameters and related information to predict future yield.

Using historical data on climate variables (annual rainfall and temperature) and RPWY in Ikot Ekpene from 2018 - 2022, a time series plot that consists of 5 observations was produced. The plot shows that annual rainfall and T_{min} were not stationary and increased over the years while T_{max} and RPWY were stationary and decreased over the years. However, there was a significant decrease in the RPWY for the years, most likely due to climate variability in those years. In this study, the forecasted values for annual rainfall from 2023 - 2030 were tested using ARIMA models. These values were then compared to the true value obtained from 2018 – 2022 in Ikot Ekpene to evaluate the forecasting performance. The best model used to forecast RPWY in Ikot Ekpene was chosen based on its forecasting performance. Forecasting results were indications for the extent of the contribution of the Ikot Ekpene tappers to the overall RPWY in the area.

Based on the performance results of different forecasting models for RPWY, ARIMA (111) was preferred because of the lowest Akaike Information Criterion (AIC) and Schwarz Criterion (SC). ARIMA model has also been used in forecasting the production of other crops such as coconut (Cristina 2015). The projected annual rainfall and temperature have been seen to be on an increase in the next thirteen years in Ikot Ekpene. The annual rainfall will increase from 381.5643mm in 2018 to 477.8097mm in 2030 while T_{min} will be from 23.84239ºC in 2018 to 24.66634ºC in 2030. This agrees with (Singini *et al.,* 2015) which uses ARIMA to model and forecast temperature variability and concluded that forecasted T_{max} will increase by 1.6°C from 27.7°C in 1982 to 29.3°C in 2030. The increase in climate variables suggests that climate variability could continue to negatively impact RPWY in Ikot Ekpene and this call for increased adaptive capacity in the area. The use of prediction models to calculate future food production for early warning and planning is prompted by the rising climatic variability and associated uncertainties, their effects on food production, and general livelihoods. Improvements in climate parameter response functions, such as temperature, have been found to constantly lower the uncertainty associated with agricultural production projection in a changing environment (Dwivedi *et al.,* 2017). The ARIMA model has been used to predict crop production with effectiveness in numerous studies. By selecting ARIMA (2, 1,1) as the best fitted model. Biswas and Bhattacharyya (2013) forecasted that paddy production in West Bengal, India, would reach 16,500.5 thousand tonnes in 2016. Sivapathasundaram and Bogahawatte (2012) anticipated an increase in rice output in Sri Lanka using the ARIMA (2,1,0) model. Other crops, like coconut, have also had their yield forecasted using the ARIMA model (Cristina, 2015). Sampson (2014) used a regression model with time series errors to explain and predict the impact of the global cocoa price on Ghana's cocoa production. (Craparo *et al.,* 2015) study on coffee indicated a tendency toward declining productivity brought on by climate change.

The ARIMA model can be used to anticipate both crop production and wholesale prices. (Singini *et al.,* 2015) forecasted the production of tiny Haplochromine fish species in Malawi using a univariate ARIMA model. Univariate ARIMA was also utilized by (Singini *et al.,* 2013) to forecast and simulate Oreochromis fish species production in Malawi. (Jai *et al.,* 2010) predicted the annual output of cattle in the Tamil Nadu state from 1970 to 2010 using stochastic modelling for cattle production. (Jai, 2011) forecasted and modelled the export of fish products in Tamilnadu from 1969 to 2008 using a stochastic model technique. The model for the production variable was regarded as the "best." Climate variable is expected to have varying effects on crop yields in different places. Depending on the region's latitude and irrigation practices, crop yields will grow in some places and decline in others. Crop yield will increase when precipitation increases, according to results from current modelling, and it turns out that crop yield is more responsive to precipitation than temperature. High water-holding capacity soils will be better able to lessen the effects of drought while preserving agricultural productivity if water availability is restricted in the future. Future water availability and crop output are probably going to decline due to temperature rise and precipitation changes. The total crop production will rise if the irrigated lands are increased, but the quality of the environment and the food may suffer.

4. CONCLUSIONS AND RECOMMENDATIONS

Prediction of climate variables and RPWY in the study area using the ARIMA model showed a negative signal that in the future, the yield may be reduced if the issue of climate variability is not properly handled. There was an increasing trend in the projected future values of T_{min} and annual rainfall but a decreasing trend in the yield of raffia palm wine in Ikot Ekpene. The study showed that RPWY in Ikot Ekpene could be predicted to be thirteen (13) years before tapping time.

Therefore, it is proven that the ARIMA model could be used as an ideal predictor to predict palm wine yield in Ikot Ekpene. The researcher recommended that appropriate climate forecasting and early warning systems should be made part and parcel of planning and development to increase the yield of raffia palm wine to improve the local dry gin industry.

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